Karlsruhe Institute of Technology

Institute of Biomedical Engineering
Kaiserstraße 12 · D-76131 Karlsruhe · www.ibt.kit.edu

12-Lead ECG Feature Identification to Discriminate Different Types of Atrial Flutter

G. Luongo, S. Schuler, O. Dössel, A. Loewe

Institute of Biomedical Engineering, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

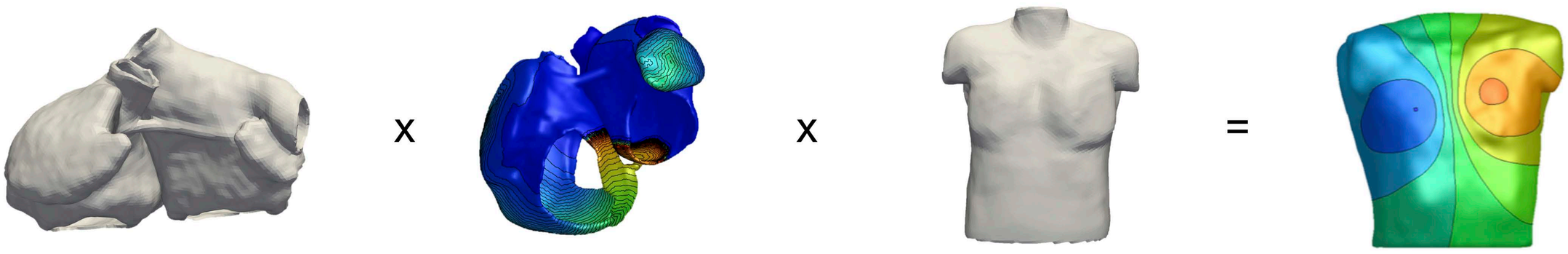
Motivation

Atrial flutter (AFl) is a common reentrant arrhythmia, characterised by a self-sustainable mechanism and an electrical signal that propagates along pathways different from physiological excitation propagation. Although AFl is not a direct cause of death, it can lead to fatal complications, such as stroke or heart attack. For this reason, it is essential to identify and recognise this condition, so that it can be promptly treated. So far, invasive methods of signal acquisition are required to reliably discriminate which type of AFl a patient suffers from[1]. To the best of our knowledge, almost exclusively morphological properties of the P-waves have been taken into consideration to identify the presence or absence of specific AFl types. To be able to distinguish different types of flutter, a more in-depth analysis must be implemented[2]. In future clinical practice, the results of this study could decrease the procedure time of the ablation therapy by helping doctors plan the interventions.

Models & Methods

Simulated signals

8 atrial geometries x 19-20 flutter cases x 8 torso geometries = 1256 BSPM simulations



- Fast Marching simulations [3]
- Courtemanche action potential of atrial electrophysiology [4]
- Boundary element method (BEM) to solve the forward problem of electrocardiography
- Extraction of the 12-lead ECG from the BSPM

Features evaluation

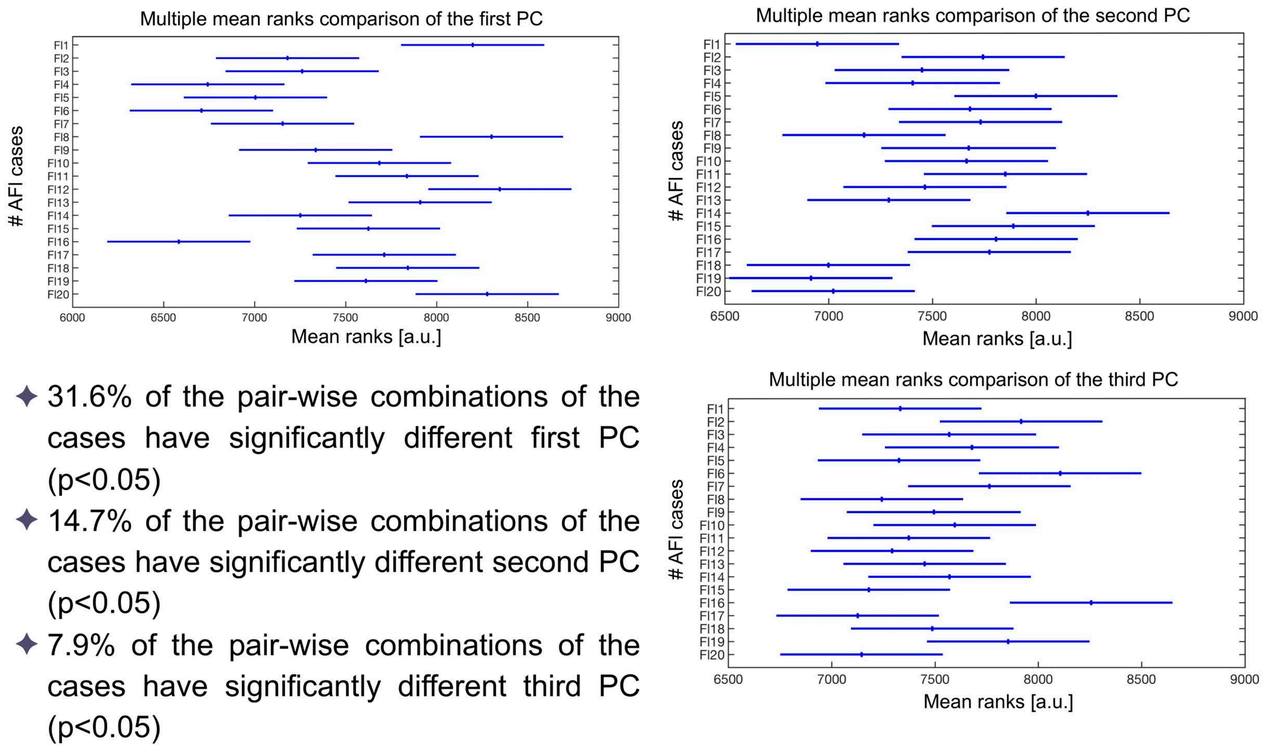
- Principal component analysis (PCA) on the 12-lead ECGs
  - Principal components (PCs)
  - Principal components scores
- Frequency domain analysis
  - Ratio of the area under the power spectrum density (rAUPSD)

Statistic analysis

- Kruskal-Wallis, multiple comparison, area under the receiver operating characteristic (AUROC) curves on the PCs
- Wilcoxon test on the PCs scores correlation coefficients
- AUROC on the rAUPSD

Results

Principal components

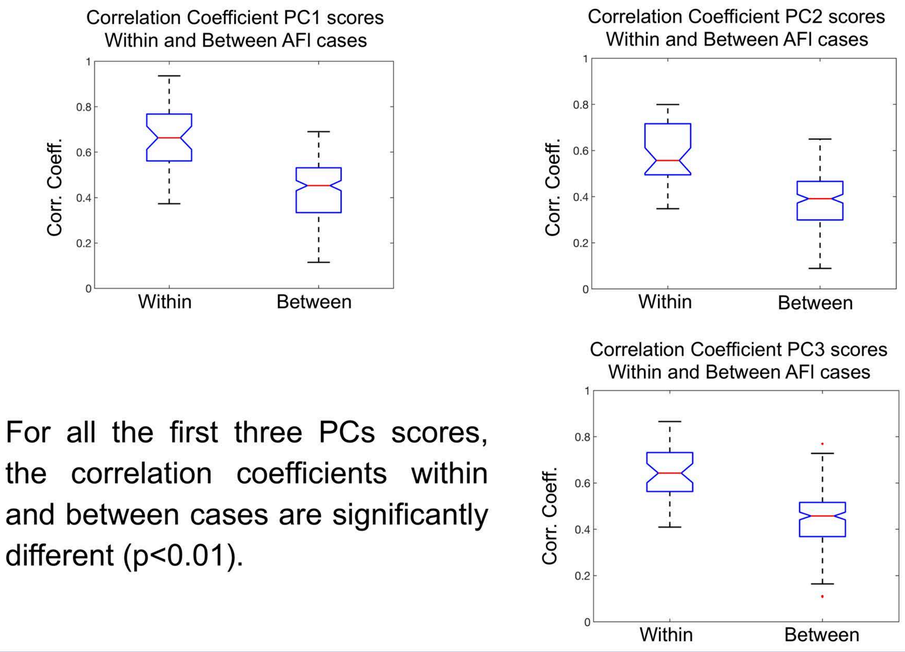


- 31.6% of the pair-wise combinations of the cases have significantly different first PC ($p<0.05$)
- 14.7% of the pair-wise combinations of the cases have significantly different second PC ($p<0.05$)
- 7.9% of the pair-wise combinations of the cases have significantly different third PC ($p<0.05$)

	AUROC [%]
First PC	56,92
Second PC	56,04
Third PC	55,22

- The area under the receiver operating characteristic (AUROC) curve shows how the respective PC can discriminate the cases.

Principal components scores



- For all the first three PCs scores, the correlation coefficients within and between cases are significantly different ($p<0.01$).

rAUPSD

	AUROC [%]
Average over 12-lead ECGs	61,2
Lead V1	60,38

- The AUROC calculated for the two parameters extracted, indicates the goodness of these parameters in discriminating the different types of AFl.

Conclusions

- The first three PCs are unsuitable discriminators when aiming at a complete separation of all the cases across all atrial and torso anatomies but they can discriminate subgroups of cases (especially the first and second PCs).
- The first three PCs scores and both types of rAUPSD, taken individually, can moderately discriminate the AFl scenarios.

Outlook

- Other features will be identified and evaluated from 12-lead ECGs and PC scores.
- The combination of the best features will be used to train a classifier. This will be subsequently tested on clinical data.

Acknowledgment

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[1] S. Bun, D. G. Latcu, F. Marchlinski, N. Saoudi, "Atrial flutter: more than just one of a kind." *European Heart Journal*, vol. 36, pp. 2356-2363, 2015. [2] P. Pascale et al., "Useful Electrocardiographic Features to Help Identify the Mechanism of Atrial Tachycardia Occurring After Persistent Atrial Fibrillation Ablation.", *JACC: Clinical Electrophysiology*, vol. 4, pp. 33-45, 2018. [3] T. Oesterlein, "Multichannel Analysis of Intracardiac Electrograms: Supporting Diagnosis and Treatment of Cardiac Arrhythmias.", PhD Thesis, pp. 114, 2016. [4] M. Courtemanche et al., "Ionic mechanisms underlying human atrial action potential properties: insights from a mathematical model." *American Journal of Physiology. Heart and Circulatory Physiology*, vol. 275, pp. H301–H321, 1998.

Giorgio Luongo
+49-721-608-45478
giorgio.luongo@kit.edu